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TO ALL OUR READERS

An Interim Measure

THE latest manifestation of unrest in the Printing Trade is a ban on overtime by the London Society of Compositors. This affects publishers such as ourselves in varying degrees according to whether their papers are produced wholly or partly in London, whether the master printer concerned has been using overtime in producing the job, and so forth.

In the case of the *Gas Journal* the result is that our printers advise us that for the time being they cannot handle more than 56 pages a week. Thus we should find ourselves back in the dimmest days of war and post-war, with severely rationed advertising and totally inadequate space to cover the current activities of the industry.

We do not accept the situation. Therefore we have made arrangements to publish separately and mail separately to each subscriber a considerable bulk of current technical matter. This is the first supplement of the kind. Similar supplements will appear, probably at fortnightly intervals, until the present Printing Trade trouble resolves itself. The supplements will be saddle stitched and can be incorporated in the week's regular issue or 'Easibind' folder and subsequently in bound volume form.

Some inconvenience will probably be entailed. We ask your indulgence in our efforts.

Enquiries for advertisement space on an art paper cover of future issues of this Supplement should be addressed to the Business Manager, Walter King, Ltd., 11, Bolt Court, Fleet Street, London, E.C.4. Telephone: Central 2236-7.

THE GASWORKS MANAGER OF THE FUTURE*

By C. H. CHESTER, O.B.E., M.I.Mech.E.,

President of the Institution of Gas Engineers; Chairman, South Western Gas Board

IN these relatively early days of nationalisation, its possible implications for the industry and its impact upon personnel are matters which appear to be exercising men's minds very deeply, and probably to an unwarranted extent due to fear of the unknown. Therefore they should be examined in a critical way so that some endeavour may be made to obtain a psychological approach on the right lines, otherwise efficiency will undoubtedly suffer due to the operation of inhibitions of various kinds.

The terms gas engineer and gas manager have been used somewhat loosely in the past, and perhaps some automatic distinction gradually evolved when, in larger works, there was sufficient purely engineering work to need the whole-time attention of one senior official, while, in smaller works, numerous duties were the concern of one individual who was the manager and, to quote a dictionary definition, not only had matters under his command or control, but had to conduct them with great carefulness.

Individual Difficulties

It is from among these two groups of people that individual difficulties are arising now and, in dealing with them, I would emphasise that each case constitutes primarily a human problem which must be dealt with on its merits, because to generalise from the particular in such matters would only result in a false façade while the real trouble still fomented in the background. In fact, the type of problem we are now discussing illustrates very forcibly, to my mind, the truth of the dictum that such difficulties consist of ten per cent technicalities and ninety per cent personalities.

Let us for a moment attempt to examine in general terms the main types of personnel which have arisen, or are likely to arise, largely as a result of nationalisation. They have arisen at what may be called sub-divisional level and also at unit level.

The second type can be divided, like so many other problems in the gas industry, into (1) short-term groups and (2) long-term groups, the first being represented by those whose works are not likely to be closed down during the working life of the personnel concerned, while the second concerns those whose works have become redundant, or will do so in the near future, as a result of integration.

We may, I think, with safety, restrict our suggestions and advice to those already in the gas industry, because the outlook of those who will ultimately enter it should be made sufficiently broad and suitably moulded by the various education schemes now in being. I use the word 'should' here advisedly because it must not be overlooked that there are two fundamental parts to the concept of education—namely, the individual and the system. It is the former which is so often the unknown quantity. I cannot resist the temptation here to digress a little and to make a few observations on education in general, because when dealing with that matter we are building for the future. It was the philosopher Diogenes who said that 'the foundation of every State is the education of its youth', and now, across the ages, new forces are stirring in the world while a new conception of education is invading even the narrow field of vocational training in which industry has previously considered its educational responsibilities to begin and end. As a result, we are now called upon to consider whether the broad educational training such as fits a man to be a citizen of the world as well as a skilled technologist should be restricted to those for whom a University education is appropriate. There have been, of course, many excellent and striking examples in our own industry of men who have found ways to supplement their technical training with that broader culture and deeper learning which has enabled them to reach great heights. To-day, however, instead of drawing those qualities from within a man, the official attitude would seem to be to attempt the imposition of them from without, and all of us, whether we realise it or not, are involved in the great adventure, because it is nothing less than that.

We should remember that in the Gas Act, 1948, Part I, Section 4, it is laid down that 'It shall be the duty of every area board, in consultation with any organisation appearing to them to be appropriate, to make provision for advancing the skill of persons employed by them, including the provision by them and the assistance of the provision by others of facilities for training and education'. Now this passage in the Act is no accident, but a definite attempt to raise the standard of education from the top to the bottom of the personnel column and, may I remind you, the student of to-day is the potential manager of to-morrow. In this 'technical age', business men—'hard-headed' and otherwise—must realise that the nation can hold its place only by the skill of its people. On the Continent, there are abundant signs that the lesson has been learned, because the French have recently initiated a residential school for apprentices in the gas industry, while, a short time ago, a report on University Reform in Germany, shows that those responsible took a very wide view of their duties because technical education and training are also dealt with. It is interesting to note that it is emphasised that the training of the student must not be restricted to the provision of theoretical or practical knowledge necessary for his future work, but that he must be made into a useful human being, as well as a useful specialist, in order to combat the danger of humanity destroying itself in this technical age. It has been suggested that technical colleges should be expanded into technical universities and their scope widened so that they would lose their purely technical character by the incorporation or weaving into the curricula a thread of humanistic thought.

Towards Broader Horizons

Since the quality of teaching depends upon the quality of the teacher, it is essential that he should see the limits of his subject-matter and show his students clearly that beyond these limits forces come into operation which are no longer entirely rational but which arise out of life and human society. It should also be shown how each subject leads beyond its own confines to broader horizons so that the student may realise the responsibility which will fall on him as a future leader of industry. In the light of these suggestions we may enquire whether the training of technologists is sufficiently wide in this country, because, as I have indicated earlier, upon the success of the education schemes we now formulate is likely to depend the future of our industry, and perhaps of the nation. Please do not conclude from these remarks that I am criticising the past or present efforts of the gas industry in general, or the Education Scheme of the Institution of Gas Engineers in particular, because nothing is further from my mind. The industry, through its various associations, such as yours, has adopted various educational measures over many years while, as we all know, the Institution has devoted much time and effort to training for all grades within the gas industry. My observations are based simply on the all-embracing argument that our numerous activities are dynamic and each must possess either a positive or a negative sign, while my general theme is that, in addition to knowledge and skill in their work, men and women

*Address to the North of England Gas Managers' Association, Newcastle, May 5, 1950.

of all classes must learn to fulfil their duty within the social entity if a new world catastrophe is to be avoided.

With that suggestive educational background, let us return to the types of problem which were set out earlier, and also, since we occupy positions of responsibility within the industry, let us speak quite frankly on this matter, otherwise we shall be wasting our time. There is no loss of dignity in a close personal scrutiny.

There are cases, fortunately not very many, although they may exert an influence quite disproportionate to their numbers, in which persons are psychologically disturbed by what has happened to them and their posts. The best way to appreciate the situation, assuming our own judgment is sound, is to 'get into their shoes' and see how we should react. Thus, in some cases, people who were, relatively speaking, a law unto themselves, now find their autonomy diminished and, in various matters, they have now to work in conjunction with other officials so that their first reaction is one of resentment and, if it is not righted quickly, the molehill becomes the mountain.

In this connection, it has been pointed out that there is thought to be considerable danger in 'concealed domination' by a few technical and political specialists. This fear is not restricted to the workers and lower technical levels but, either openly or by implication, at much higher levels, and it must be removed. My own view is that, in practically all cases, their previous training, experience, and breadth of mental outlook will enable them to surmount the barrier, because, viewed dispassionately, their loss of status is imaginary and not real. Their new positions, as members of a team, are just as important, often more so if they take a broad view of their responsibilities, than formerly, since frequently they are in ultimate charge of a greater number of works. The fact that certain decisions now have to be taken in conjunction with other officials should be helpful rather than otherwise, because the other man's point of view, and the interchange of information thus brought about, can only be stimulating. In any case the man who says he can't is usually right.

Personnel Adjustment

The question of personnel adjustment on large works is, I think, a matter which will, in the main, right itself with the passage of time, particularly as the organisation as a whole shakes down and the various misunderstood pinpricks either disappear or assume their proper perspective, but, I submit, there is a more difficult problem presented by the personnel of those small works which, as previously mentioned, may be closed down as a result of integration. Many of the people concerned have received a shock, and feel that there is no useful part for them to play in the whole organisation. This, in most cases, is quite wrong, because in the past their duties have been so numerous and varied that it has been impossible to attend to all of them satisfactorily, and many aspects of the business have suffered, particularly distribution and consumer service. Here then is a chance to show these personnel that there is an excellent opportunity for them to do something really worth while for the industry and themselves. The large producing units will supply them with the gas so that all their previous worries in that connection—and they were very real—will disappear, and they can then concentrate their whole energies upon the needs of the consumer. Time and again one finds that the distribution service in these smaller undertakings has failed miserably; poor pressure, too much variation in pressure and calorific value, and maintenance of appliances poor or non-existent. I am making this observation on actual experience since vesting day. So long as they realise that the better the service given to the consumers the less it costs to serve them, I am sure that the overall effect will be to build up a goodwill of inestimable value. It has been well said that a competitor can cut prices, but when you sell personal service he is up against it.

It may be rather difficult at first to make the necessary adjustments of outlook, but those who are prepared to accept a little healthy mental discipline will find the effort very rewarding.

They must, of course, be prepared to accept responsibility, and in that connection I was particularly interested in the definition which my friend Edward Crowther gave of it in his address to the Northern Junior Gas Association last March. He was, you will recollect, speaking of the Northern Gas Board's attitude towards the exercise of responsibility. He said: 'Its essence is an ability to understand when circumstances within one's province call for action, to decide correctly what action, perhaps from among a number of possible courses, is the best, and to take that action. It also requires the ability to convey to the minds of others a recognition that action is required, and that the intended action is well selected.' We can commend that to the juniors and remember it ourselves.

It need hardly be emphasised that, with such changes and variation of duties, the personnel must, of course, be treated fairly and consistently with regard to emoluments if they are to have confidence in all that is being advocated.

Before sketching in outline an idea of the gas manager of the future, we may consider briefly the changed industry he will have to serve. The situation is somewhat like the house that Jack built, for without satisfactory service to the consumer the industry cannot exist, and without industry the State cannot survive. The planners with their plans, the councils, conferences and committees, the liaison and public relations officers, all are of no avail unless there are free and vigorous industries to provide, directly or indirectly, those things which make a reasonable human life possible on the earth. Of the industries in this country the gas industry occupies a vital place and no industry recognises more clearly that the well-being and co-operation of staff and workers are essential elements in the successful and efficient administration of such a complex undertaking. Such an outlook is vital, because I think it is correct to say that more businesses break down because of inside weaknesses than as a result of external competition. We shall, naturally, be subject to increasing public scrutiny and be judged, more than in the past, not so much by the position we are in as by the way we fill it.

In the future, therefore, apart from the specialists in the large gas-producing units and those concerned with distribution, we shall have available a considerable number of important people who were originally in charge of small works. These people will be our ambassadors in their own provinces, and will have numerous opportunities for the use of tact and initiative. I hope sufficient has been said to reassure the manager, particularly of a small works, that he still has an important future.

GAS AS A TURBINE FUEL

Reviewing industrial gas turbines during the May Lecture to the Institute of Metals, Dr. H. Roxbee Cox, Chief Scientist to the Ministry of Fuel and Power, discussed peat as a gas turbine fuel, pointing out that the first steps towards the closed cycle peat gas turbine are being taken by John Brown & Co., Ltd., who are making an air heater for their 500-h.p. set to take peat of 30% humidity. Ruston & Hornsby are making a version of their 750 kW. set to run on peat. There is, of course, with peat, as with coal, an ashing problem, and similar means of cleaning are envisaged. As peat seems likely to be somewhat less abrasive than coal ash, it is possible that a somewhat lower standard of cleaning may be permissible. Regarding gas as a turbine fuel, reference is made to gas from underground gasification of coal, and to 'firedamp' or methane in mine upcast air. If this methane could be fully used in efficient engines it could generate all the power the collieries require. The fact that methane rarely occurs in the upcast air in concentrations higher than 1% is not basically a disadvantage, as an air/fuel ratio of 100/1 is of the right order for a gas turbine. To get such a mixture to burn, however, a considerable amount of pre-heating is necessary. Coke oven gas is an interim possibility, but the ultimate aim is to bring together two lines of experiment—firedamp investigation on the one hand and the coal-burning gas turbine on the other. The target is a gas turbine plant which consumes both firedamp and the colliery fines available at pitheads.

MOULDED REFRACTORY BURNERS*

By W. N. SMIRLES, B.Sc., A.R.I.C., M.Inst.Gas E.

Development Officer, Industrial Department, West Midlands Gas Board, Birmingham District.

This paper gives an account of the design, construction, and performance of a special type of moulded refractory burner to be used for local heating in industrial operations. The burner consists of a short converging tunnel at the base of which theoretical air/gas mixtures are burnt. The flames are formed at the mouth of a series of slots in the base of the tunnel, which base is moulded integral with the tunnel walls. The performance of these burners is gauged by the heat imparted to a circular water tube across the tunnel mouth, and the results are related to standard data on forced convection.

IN industrial operations occasions are often arising where local heating of a component is required. Such heating may take the form of a fusion as in glass manipulation or silver soldering, local softening or annealing as in metal fabrication, or heating prior to local hardening. Of necessity the Birmingham undertaking has always had a keen interest in this work and papers† have been read by other members of the staff to throw considerable light on the subject.

The present work originated as the result of requests from two manufacturers who required what we may call 'contoured' flames for certain fusing operations. The burner system adopted after many attempts had some very good features and though it resembles in some characteristics other forms of local heating burner, there are some aspects of its manufacture and performance that are worth attention. Accordingly, though its ultimate form is not yet decided, it is considered that the time is opportune to present an account of it to those interested in industrial burners.

It is not proposed to review other types of contact burners, descriptions of which will be found in the papers referred to. References will be made to them as points of comparison arise.

Requirements for Burner for Local Heating

The factors which influence the success of a burner for local heating may be considered under the following headings:—

1. The shape, size, and position of the flame.
2. The temperature of the flame and the ready reproducibility of the flame characteristics.
3. The velocity of the products of combustion as affecting the rate of heat transfer by forced convection.
4. Other factors: performance of burner, silence, flame proofness.

Positioning of Flame

For a flame to be so disposed to the surface or edge to be heated that it is used to the best advantage demands a burner designed for each particular purpose (as the one I propose to discuss) or a burner which can be built up from a number of sections, as certain strip burners available, or a number of small units suitably placed

Our early attempts to make a contoured burner were in the nature of converging tunnel burners fired by a drilled mixture manifold at the back. Owing to a lack of uniformity in the flame this was discarded in favour of a refractory grid, moulded for convenience with slits and not with circular holes. This was later superseded by the present design with walls moulded integral with the grid.

The converging burner tunnel in which combustion takes place, is formed in a refractory block which constitutes one boundary of the mixture manifold, the other boundary being the welded steel box in which the block is rigidly retained. Air/gas mixture from a suitable mixing device passes to the tunnel proper through a series of properly proportioned slits, connecting manifold and tunnel, and there burns to give a very hot and rapid stream of products of combustion which may be accurately directed from the tunnel mouth on to the work to be heated. See Figs. 1, 2, 3, 4.

Before I describe to you the operation of making such a burner system I should say that in the early days of our work on these problems our attention was drawn to the possibilities

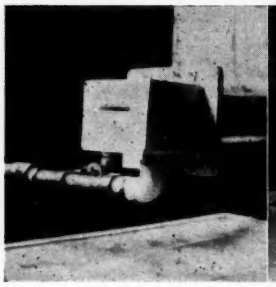

Fig. 1

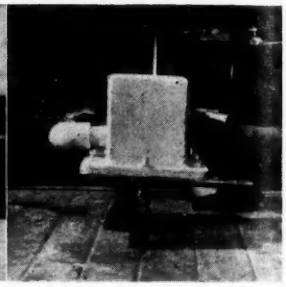

Fig. 2

Left: General view of burner, slot 2 *in. long. Right: Burner in operation. End elevation of flame* 3/5 *in. wide.*

of silicon esters as bonding material for high grade refractory special shapes, and our technique of moulding proceeded concurrently with that of burner design.

The silicon esters as available commercially have the composition $Si(OC_2H_5)_4$ and they can be hydrolysed—*i.e.*, caused to react with water to produce a silica gel which, if dispersed among suitable refractory grains, can be dried and fired to give a very strong bond. The hydrolysis is effected by mixing with the ester a water-alcohol mixture, the water content of which

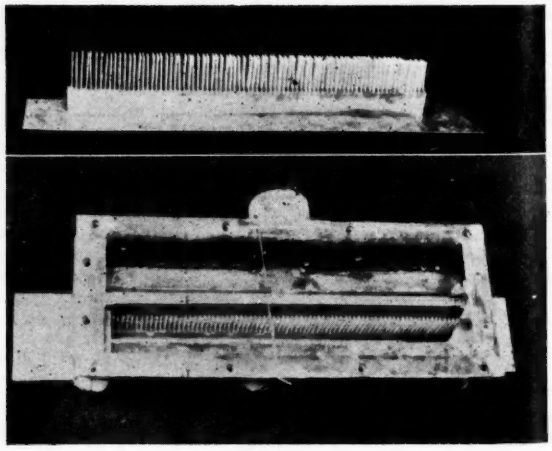

Fig. 3 *and Fig.* 4

Stages in construction of moulded burner (slot 12 *in. long x* $\frac{1}{4}$ *in. wide). Above: Tunnel core and pins erected on base plate. Below: Box with H.T.I. lining fastened over core and fins 'dressed'.*

* Paper to the Midland Junior Gas Association, March 28, 1950.

† J. Palser. The Concentrated Combustion Burner. M.J.G.A., November, 1945.
J. F. Wright & J. Palser. Furnaceless Heating. *Industrial Gas*, March, 1947.
J. F. Waight. M.J.G.A., March, 1949. *Industrial Gas*, November, 1949.

can be varied within limits, to control the process of hydrolysis and rate of setting. Various refractories may be used—*e.g.*, sillimanite, zirconia, alumina, &c., subject to suitable nature and size of grains. For success the grains must not be rounded but sub-angular, and a mixture of small and large should be used. We have used throughout sillimanite grains of mesh −30 +80 and sillimanite flour, which gives very sharp mouldings—a necessity when fine orifices are to be formed.

Moulding Operation

A wooden core corresponding to the desired tunnel shape is pinned, mouth down, to a flat base plate, and on its ½ in. wide upper surface a series of shallow slots is cut with a hack saw, at specified distances, to take fins to form the combustion slits. These fins are of stiff card or plastic of correct gauge and guillotined to size ½ in. × 1¼ in. Over this tunnel core is clamped the burner box with back removed and with its front edge lined with H.T.I. brick, so sized as to come within ½ in. on every side of the projected tunnel mouth. The H.T.I. is closely fitted and cemented into position and moreover retained at the sides by strips of iron pinned to the sides of the box. Into the mould thus formed the correct amount of sillimanite, ester, and alcohol mixture is poured, to cover the fins to within ¼ in. of the top, vibrated to fluidise and consolidate the mass, allowed to set, dried, and fired to about 700°C. After blowing out the ash and generally cleaning up, the back is sealed into position and the burner ready for use.

The size and separation of the slots to be formed in the base of the tunnel were originally founded on the consideration that with relatively large manifolds the burner should be flameproof. Limiting diameters for circular holes to prevent light back in theoretical mixtures should be of the order of 1·8 mm. (0·071 in.). In point of fact, about half this width is essential. Other considerations, however, require the slot width to be 0·020 in. or less, so that these burners are well within the flameproof limit.

The ratio of slot area to base of tunnel is based on the relative volumes of unburnt gas and expanded products of combustion, so that for slots of 0·020 in. width the spacing required is 7·5 to the inch (practical ⅛ in. centres). The tunnel base has, from strength considerations, been kept at ½ in. wide. The tunnel length and aperture depend on the concentration and required dimension of flame, and will be considered under the heading of velocity of products of combustion.

Optimum Flame Conditions

The next consideration is that of getting optimum operating conditions—*i.e.*, of regulating air and gas to give maximum flame temperature which corresponds in a practical sense to theoretical proportions of gas and air.

For the tests and regulation of this burner we have availed ourselves freely of a device due to Brinsley and described in a recent paper* to the Institution of Gas Engineers. Known as the calyx flame this device is such as to give a degree of precision to manifold burner adjustments which could not be obtained by any other means, and in fact is invaluable for both laboratory and district work. For example, reference to Table 2 shows five independent adjustments of gas rate to a standard air setting for five different venturis, fitted to the air entrainment device and indicates the exactness with which the adjustments can be made.

The calyx burner is fed by a bleed from the air-gas manifold and the mixture flame is caused to burn in its own products of combustion, with rigorous exclusion of extraneous air. If in the mixture there is air in excess of that required for combustion, then no violet calyx is formed at the base of the flame, but immediately on reaching theoretical mixture proportions a calyx appears and intensifies in colour on further enrichment with gas.

Using, as will be described later, a small water cooled tube in the flame as an indication of heat transfer, a series of tests was made with a small moulded burner with a constant air flow and variation of the gas entrained. The results are given in Table 1.

These figures show that for over-aerated conditions the heat transfer is not unduly affected by excess of air. With excess of gas, however, heat transfer rapidly falls off once calyx conditions are passed. When heating a hot body, however, a different result will be obtained on account of the serious diminution in temperature difference. In practice with brazing tests it has been found that much the best results are obtained when strict attention is paid to the regulation of the burner. For all tests, therefore, calyx adjustment was used.

The burner, being of a manifold type fed by an injector, is capable of use by entraining air at atmospheric pressure, giving constant proportioning of mixture and reproducibility of mixture and flame characteristic.

Maximum Velocity

Even with the hottest flame suitably disposed to the work it may still be necessary to use the maximum velocity of products of combustion—*e.g.*, in local heating of metals where thermal conductivity is so important, speed of heating is essential. Or again it may be necessary to make the best use of available air pressure. We must, therefore, examine the problem of producing maximum velocity of products of combustion on to the work. This velocity will all have its origin in the energy of the air jet which energy will appear partly as static pressure in the manifold and static pressure at the base of the tunnel which latter pressure accelerates the gases towards the mouth when the tunnel is convergent. The conditions for the successful accomplishment of this energy conversion have been laid down in a paper already referred to and the results given form a very satisfactory confirmation. I am giving in Table 2 a number of sections of a complete test of a burner system which could be fitted with five sizes of venturi and in which the air jet was increased progressively in stages.

Burner dimensions:
Mouth 3 in. × ¼ in.
Slots 17 × 0·024 in. × ½ in. of area 0·204 sq. in.

The following points are of importance:—

1. In each series of tests venturi No. 3 gives the maximum manifold pressure and maximum gas rate corresponding to calyx conditions. For this optimum size of venturi the ratio of throat area to port area was 0·435 in.
2. As the size of this jet is increased and the ratio of the

*Brinsley—June Research Meeting, Inst.Gas E. Gas Heat in Industry August, 1949

TABLE 1

Aeration Condition	Gas Flow cu.ft./hr.	B.Th.U./hr. measured	B.Th.U./(thous.) sq.ft./hr.	B.Th.U./(thous.) sq.ft./hr./cu.ft. of gas
Over aerated, no calyx	66·5	875	312	4·7
– ditto –	70·6	992	354	5·0
– ditto –	75·9	1061	379	5·0
Faint calyx	78·5	1095	391	5·0
Pronounced calyx	80·7	1073	383	4·75
– ditto –	81·5	940	334	4·1
– ditto –	88·5	955	340	3·84

TABLE II. Tests to determine optimum diameter of venturi for use with a given burner and corresponding pressure and flow relations.

Air jet dia. in. d.	Venturi Throat dia. in. D	Ratio $\frac{D}{d}$	Gas Pressure in. w.g.	Manifold Pressure in. w.g.	Gas Rate cu.ft./ hour.	Suction at point of entrainment	Condition gas & air full on
0·241	·281	1·17	3	7·7	126	— 6·9	overgassed
	·312	1·29	3	8·4	131	—12·4	,,
	·336	1·39	3	8·4	132	—12·5	,,
	·360	1·49	3	8·2	128	— 9·75	,,
	·385	1·60	3	8·0	127	— 8·05	,,
	·281	1·17	0	8·0	127	— 6·9	,,
0·281	·281	1·00	3	12·4	164	— 1·5	,,
	·312	1·11	3	13·15	171	— 4·4	,,
	·336	1·20	3	13·15	171	— 5·2	,,
	·360	1·28	3	13·0	169	— 4·65	,,
	·385	1·37	3	12·95	168	— 3·7	,,
	·385	1·37	0	12·95	168	— 3·7	,,
0·306	·281	0·92	3	14·4	170	+ 2·4	no calyx
	·312	1·02	3	15·3	188	+ 0·5	overgassed
	·336	1·10	3	16·0	193	— 2·1	,,
	·360	1·18	3	15·9	192	— 1·6	,,
	·385	1·26	3	15·6	189	— 0·9	,,
0·320	·336	1·05	3	16·7	199	+ 1·5	,,
	·360	1·12	3	17·0	202	+ 1·3	,,
	·385	1·20	3	17·0	200	+ 0·5	,,

diameter of the venturi to that of the air jet approaches 1·1 so maximum manifold pressure and gas flow are developed.

3. Within the size limits laid down above automatic proportioning due to governing to atmospheric pressure is possible.
4. It is worthy of note that the maximum manifold pressure corresponding to 40·8 in. w.g., air pressure is 17·0 in. w.g. which corresponds to 42% conversion. This serves as a guide to the efficiency of energy conversion.

These data lay down, for our gas, the approximate proportions of an injection system and burner, but are subject to certain limitations.

The effective aperture of the burner is not that of the slots alone for the resistance of the tunnel beyond these slots also has an effect on restricting the escape from the manifold. In fact the pressure developed at the base of the tunnel is fairly considerable, as the following figures for a tunnel of taper 21° (included angle) would show.

Air pressure, in. w.g.	6·8	13·9	26·2	56·1	111·2
Manifold ,, ,, ,,	3·5	5·6	9·7	17·7	30·4
Tunnel ,, ,, ,,	0·5	0·8	2·1	4·3	7·7

From these figures it would follow that the ratio of possible discharge without tunnel, to that obtained with the tunnel, is 1 to 0·93 for the lower air pressures. In other words for this very convergent tunnel the tunnel is equivalent to a reduction in grid size of 7-13% according to the air pressure. For most purposes, therefore, this correction can be neglected.

It might be noted at this point that the discharge coefficient of the slots varies from 0·37 to 0·5, which is the result of a temperature effect, the mixture tending to heat up at low rates of throughput.

To make the most efficient entraining device for a high velocity burner the following size relations must hold:—

Tunnel length (in.) × $\frac{1}{2}$ in. = tunnel base (sq./in.).
Tunnel base (sq. in.)/6·8 = slot area (sq./in.).
Slot area × 0·45 = venturi area giving venturi dia. D.
D/1·1 = air jet diameter.

If a low velocity burner is being made, then a proprietary make of injector approximating to the above, may be fitted.

Velocity and Tunnel Shape

In the early stages of the development of this burner we had little to guide us in the matter of optimum tunnel shape. The object of the burner being at times to use the greatest velocity locally, it was realised that we could effect this by making the tunnel more convergent, but quantitative measurement of the effects produced was not forthcoming until we adopted the simple technique of using a water cooled tube across the burner mouth as an index of heat transfer.

The tube used for these tests was of polished heat resisting steel 0·126 in. outside diameter and 1/16 in. inside diameter. A suitable length of this was soldered into two brass bushes which could be screwed into $\frac{3}{8}$ in. tee pieces with accommodation for a suitable accurate thermometer and appropriate connections for water inlet and outlet. The inlet was connected to a constant head tank and the flow of 1 lb./min. gave a suitable temperature rise with all burners. It was established first of all that within reasonable distance of the burner mouth consistent results of heat transfer could be registered. Thus with a 2 in. × $\frac{1}{8}$ in. slot burner working at 48 cu. ft. per hr. the following data were observed:—

Distance of tube above burner mouth... ...	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.
Heat transfer. B.Th.U. per hr. registered ...	1,550	1,555	1,550	1,450	1,340	1,175

In all tests, however, the distance from the burner mouth was standardised at $\frac{1}{4}$ in.

Heat Transfer—Calculation of Convected Heat

The fact that the burner orifice is ideally suited to heating a tube is of great importance because it enables us to calculate the amount of heat transferred by forced convection during any test. The total quantity of heat transfer (convection and radiation) being accurately determined, the radiant heat transfer follows by difference.

A great deal of work has been performed on the heating of circular section tubes in streams of hot fluids (liquids and gases) and all the data for widely differing conditions of temperature difference, tube diameter, velocity of fluid, and fluid characteristics can be related to each other by an expression of the form.

$$\frac{Hd}{k\theta} \Big/ \left(\frac{c\mu}{k}\right)^{0.3} = \left(\frac{dv}{\mu}\right)^{0.6}$$

This applies to high velocity streams where $\left(\frac{dv}{\mu}\right)$ the Reynolds number has a magnitude greater than 1,000.

In this formula the symbols represent:

- h = heat transfer in B.Th.U. per sq. ft. of tube surface per hr.
- d = tube diameter (ft.).
- θ = temperature difference between fluid and tube °F.
- v = mass velocity *i.e.* lb. fluid per hr. per sq. ft. of burner aperture.
- c = specific heat at constant volume.
- μ = viscosity of fluid.
- k = thermal conductivity of fluid.

c μ and k are obtained from standard data on gases and the value of $\frac{c\mu}{k}$ which appears in the formula is taken as constant at all temperatures. These data are obtained for the mean temperature of the film between fluid and solid.

The mass velocity of the fluid is obtained from the gas rate, theoretical air requirement, and burner orifice. For a calculation of h therefore, it is necessary to determine the flame temperature or assume a reasonable value for same. The determination not being possible it was decided to adopt a figure of 1,850°C. for the flame temperature. Recent results by Leason* working with similar types of converging tunnels indicated flame temperature of this order. In the event of this temperature being, say, 100°C. too high, then the error introduced with a calculation of convection to tube at 30°C. would be approximately 6%.

Application to Tunnel Design

In our early work on this type of burner we had remarked on its curious behaviour with increasing mixture feed. Thus a burner working at a low air pressure of ½ lb./sq. in. would have the tunnel walls at a temperature of perhaps 1,250°, but on increasing the air pressure and gas consumption to retain calyx conditions the temperature of the tunnel fell and finally became relatively cold. Reference to Section 1, Table 3, illustrates this.

Our first application of heat transfer measurement was to determine the cause of this and a series of tests was performed with a 2 in. × ⅛ in. slot burner of which the grid had 11 slots ½ in. × 0·025 in. The heat transfer performance is set out in Table 3, Section 1. We note that the heat transfer rises sharply to a definite maximum at 40,000 B.Th.U/hr. input, after which further increase of mixture feed leads to no appreciable increase in heat transfer.

This phenomenon, which indicates a reduction in flame temperature, has been ascribed by Leason to turbulence at the point of combustion. At the point of maximum heat output which will correspond to fully turbulent conditions in the cold

* Leason. University of Leeds Library. Private Communication.

TABLE 3. HEATING PERFORMANCE OF SLOT BURNERS

Burner	Grid Slots	Gas Rate cu. ft./hr.	Heat Transfer Observed B.Th.U./ sq. ft./hr. (Thous.)	Heat Transfer Convected Calculated B.Th.U./ sq. ft./hr. (Thous.)	Heat Radiated B.Th.U./ sq. ft./ hr. diff. (Thous.)	% of Total Heat Radiated	Tunnel Wall Temperature °C.
Section 1.							
1 in. long	0·5 in. ×	30	215	155	60	28	1240
tunnel	0·025 in.	50	282	199	83	29·4	1290
taper ½ in.		63	315	224	91	28·8	1250
to 0·142 in.		78	345	238	107	31·0	1180
		96	363	270	93	25·6	1080
		112	356	296	60	16·9	patchy
		138	358	335	23	6·4	,,
		174	360	385	–25	–	cool
Section 2.							
1 in. long	0·5 in. ×	40	200	125	75	37·5	1160
tunnel	0·017 in.	58	242	155	87	36	1260
taper ½ in.		81	287	186	101	35·2	1310
to 0·264 in.		111	345	218	127	36·8	1260
		135	386	228	158	40·9	1260
		155	417	248	169	40·5	1200
		175	433	266	167	38·6	–
Section 3.							
1½ in. long	0·5 in. ×	36	222	160	62	28·0	1240
tunnel	0·017 in.	54	282	194	88	31·2	1320
taper ½ in.		77	342	234	108	31·4	1380
to 0·16 in.		111	408	274	134	32·8	1380
		132	438	304	134	30·6	1440
		177	516	362	154	29·8	1430
		225	576	422	154	26·7	1440

mixture stream the Reynolds number has a value of 3,070. There is a definite change in direction at a heat input of 24,000 B.Th.U. at a Reynolds number of 2,000. These figures are a good indication that turbulence is playing a big part. Moreover the following tests tend in the same direction. It was decided to make some burners with narrower slots, keeping the burner port constant and so to get mixture flows of lower Reynolds number. Two burners were constructed with slots of width 0·017 in. and 0·008 in., the latter being a strip metal grid. The results of tests on these burners certainly show considerable increases in the capacities of the burners with diminishing width of slot. Turbulence due to slot width may not be the only disturbing factor at higher mixture feeds, but tunnel convergence may be playing an important part.

It had formerly been noted that with large slots discharging into a small taper tunnel that the phenomenon of maximum heat delivery had been observed, but we had not tried a small taper tunnel with small slots. This was, therefore, done next, and in Section 2 of Table 3 the results are given to show little indications of change in direction, and in fact its performance eventually equals that of the narrower tunnel B with its greater mass velocity. In the case of the wider mouth tunnel a greater proportion of the heat is transmitted by radiation. There are thus grounds for supposing that tunnels of smaller taper would be an advantage and it was decided to make a tunnel of taper 14° included angle and get a mass velocity at the mouth equal to burners A, B, and C by extending the length of the tunnel to 1½ in. The results are given in Section 3, Table 3.

It should be noted that the slots were 0·020 in. width so that a considerable improvement is shown by making the tunnel taper less. The change of cross-section due to a 14° included angle on a straight tunnel corresponds to that due to a 7° included angle on a circular section and is, therefore, in harmony with general practice. With small taper tunnels there does not seem to be much point in making the slots less than 0·020 in.

Of the various burners constructed we may regard the performance of that marked E as typical and summarise it as follows:—

Air pressure, lb./sq. in.	½	1	2	3
Gas consumption, cu. ft./in. length of tunnel	27	39	55	66
Gas rate, cu. ft./sq. in. tunnel aperture for ⅛ in. wide tunnel	216	312	440	528
B.Th.U. developed per cu. ft. of tunnel space—mill.	40	58	82	98

Miscellaneous Considerations

One of the most important considerations is the life of the refractories. As regards the tunnel walls the temperature will be shown in Table 3 varying with rate of working but is well within the scope of the high grade sillimanite used. The slotted grid is at a much lower temperature and trouble is not anticipated here. Burners have been in use (40 hours per week) for a year under rather disadvantageous conditions with very encouraging results. Some readily replaceable unit construction which could be pre-fired and cemented into position as required, seems to be called for.

Coupled with this question of life is that of the strength of the refractory block. For low pressure working up to 2 or 3 lb. there seems to be little doubt (though it has not been made the subject of test) that the refractory is strong enough. For high pressure working extra support of the refractory, with possibly a metal grid, may be required.

Another important consideration, especially where the burner has to be tended, is that of noise. At low ratings, up to 2 lb. air pressure, the burner would be regarded as quiet. Above about 4 lb. air pressure the noise would not generally be permissible.

Some Industrial Applications

A number of burners have been supplied or are on order for the silver soldering of components of oil lamps. Such operations require the precision and shape of the flame more than intensity other than that of correct mixture adjustment. Air pressures of 1 lb./sq.in. are adequate. With such small tubular and pressed assemblies mounted on a turntable and 2 in. slot burners directed across the work, fusion times of 40 to 60 sec. are attainable. A fair degree of overheating is found to be possible, a component fused at 40 sec. being unharmed by 60 sec. heating so that with proper attention wastage should be reduced, the process can be fully mechanised or left to individual attention.

A brass boss to be soldered to the centre of a ½ in. brass tube by two silver solder rings required 50 sec. for the first ring and 10 sec. for the second on rotation into position. The total gas consumption for the two burners required was 50 cu. ft./hr. Semi-skilled labour could be employed.

A firm of manufacturers of steel blades required a local softening of a narrow strip 2 in. × ¼ in. wide across the handle —a time of 18 sec. not to be exceeded. A time of 15 sec. was attainable, the gas consumption for the burner being 100 cu. ft./hr.

Experiments are on hand for the local hardening of two cutting edges of special cutter blades of section about 1 in. × ¼ in. This relatively heavy section requires about 80-95 sec. for bringing the edges to hardening temperature at 1½ lb. air pressure.

A great deal of experimental work has been performed on edge fusion of glassware for which the burner was originally devised. This work is still in hand.

It is felt that this burner is capable, perhaps in a somewhat restricted field, of rendering some very good service in industrial heating. The essential features of its design have been established by the means described and its performance coincides with the maximum effort of which forced convection, assisted by radiation, is possible. Though simple in outline it yet remains for us to put its construction on a really sound basis.

I have to thank the authorities of the West Midlands Gas Board, through the Industrial Gas Officer, for permission to give this paper and to acknowledge much help and advice from colleagues in the Industrial Department at Birmingham. In particular I should mention the name of Mr. W. Coull, whose assistance has been invaluable.

DISCUSSION

The **President** (Mr. S. C. Bentley) particularly liked the way in which Mr. Smirles showed what he was after by giving examples of work to be done before explaining how the result was obtained. With reference to work on the metal parts which wanted such a concentration of heat, he wondered how the use of gas compared with what he thought they called induction heating by electricity. In describing the theory of the burner, Mr. Smirles had shown in Table I that the actual heat obtained from the combustion of quite considerable quantities of gas was relatively low, but he thought perhaps later on the explanation came inasmuch as the water-cooled tube was not to measure the total output of the burner but, presumably, to give an indication of relative performance. Was that right?

Mr. **Smirles:** Yes, it is purely small burner performance.

Mr. **Bentley** continued that that construction was on a very small scale, and it was amazing that apertures of 8,000th of an inch could be obtained in sillimanite. Would it be possible to make the apertures circular and would that be a more simple construction if a form of steel-like needles could be put in the mould and sillimanite could be quite effectively bonded round it. If there were multiple small holes instead of slots, this would give, he thought, less risk of flash-back and, also, would give a greater hole area for the area of the burner than that given by the slots. One other point was that the taper of the aperture apparently set at 21° and then reduced to 14°. He would have thought that, if work were done during or at parallel on the velocities quoted, the risk of lighting back would have been very low even with a parallel temperature. The increase in velocity would still obtain by the rapid increase of the unburned gases reaching and exceeding the temperature.

Mr. **Smirles** said one of the most expensive things they had to contend with was labour. Although some efficiencies of heat transfer were comparatively small, they were rapid and they could be put on a satisfactory mechanical basis and could be made a profitable consideration. Mr. Bentley had raised the question of a reduction in slotting. He hoped to keep that

rather in the background because he would not like to think, as some might do, that they had in that type of burner a complete answer to induction heating. Of course, they had known that those burners, as they were made at the moment, could be put on a satisfactory basis of manufacturing even if they were considerably more expensive, because they might still be profitable for the reason that, in the course of a few weeks' working, they could recoup the cost of the burners; and they had not got the overhead costs, the capital charges which were associated with induction heating. When they went down to 8,000th of an inch in the slots, they actually used a metal grid. It was to establish an experimental result that they got down to such fine apertures. In the last experiments on the convergence of the tunnel shape, there was no necessity to get down below 20,000th of an inch slot, where they could begin to mould mixtures satisfactorily. The taper of the tunnel was under pressure, but not from the point of view of lighting back. The walls were, of course, flame-proof. The tunnel was not flame-proof; it actually lit back into the tunnel.

Empiricism *v.* Mathematics

Mr. **J. F. Waight** (Birmingham) pointed out the principle of the burner was not new, since it was similar to the Selas cell and ribbon burners, and others. The author did well to indicate the application of silicon ester bonding to the production of precise burner ports—a process likely to be more widely employed in the future for that purpose. The paper gave an interesting account of some convection heat transfer experiments, from which it would appear that convective heat transfer data obtained in work on relatively low temperature gas was valid at the high temperatures and velocities obtaining in products of combustion issuing from pressure air-gas burners, a conclusion reached by Kilham and others working in that field of investigation. The calyx burner was an excellent means of indicating the existence of a completely aerated mixture, but it was unfortunate that the author had used that burner to the exclusion of mixture analysis, since mixture analyses quoted in conjunction with pressures, velocities, port sizes, and rates of heat transfer would have enabled other workers to use the paper as a basis for further experiments. He (Mr. Waight) was surprised, also, that Mr. Smirles had employed an empirical method of determining the correct size for air jet, venturi throat, &c., when there was available a sound mathematical method which would have enabled him to achieve the same result in a fraction of the time. With regard to Section 1, col. 6, in Table 3, Mr. Waight continued, was the author not placing too much strain on his calculations when, by quoting a negative rate of heat transfer, he suggested that the steel tube was losing heat to the tunnel?

Regarding the phenomenon the author had observed of maximum heat imparted to the tube, the author had discussed the possibility of flow states corresponding to Reynolds number of 2,000 and 3,000 as causing that peculiar behaviour. He (Mr. Waight) felt that flow within those Reynolds number ranges was likely to be uncertain as it was precisely between those two numbers that flow was likely to be either streamline or turbulent, and certain turbulence was not achieved until the Reynolds flow number exceeded 3,000. He asked whether the author had examined the mechanical energy distribution in the hot gases as they flowed through the converging tunnel. Bernoulli's theorem suggested that there was a minimum area for the exit slot, and, if the area was below that value, he would suggest the effect the author had noticed would be likely to occur. The fact that the longer tunnel had cured the trouble within the limits of the author's experiments suggested to him (Mr. Waight) that the increased cooling or heat exchange surface afforded by the longer tunnel brought the gases to a temperature at which, with the available mechanical energy, they could be discharged from the slot after combustion had been completed.

In that connection, it was interesting to note that tunnel D, having ¼ in. wide slot, exhibited no fall off in the rate of heat transfer. He was sorry that the paper had not included some comparative figures which would have shown the results on burners of simpler construction. The burner described was an excellent burner, but was expensive to make, and he was not certain that its performance was superior to existing equipment of more conventional design.

He did not regard the 42% efficiency of energy conversion as being good, and was sorry to see that the author had used a figure of concentration of combustion based on the volume of the tunnel. Combustion commenced at some distance beyond the grid and was completed some distance beyond the exit port, and took place within what was possibly a series of stationary waves. The volume of that wave system would be difficult to assess, but it was certainly not the volume of the tunnel, and to use a figure based on the volume of the tunnel was, he thought, inaccurate and misleading. The paper indicated the work which was being done and must be done to improve, in a scientific manner, the application of gas to industrial heating processes, and the author was to be congratulated on the work he had put into its preparation.

Mr. **Smirles** said he had expected some rather severe criticism; in fact, to have a criticism of the nature of Mr. Waight's was to the good. There was much that was akin to the American cell burner which they had now had the good fortune to examine in Birmingham. Its performance, as was to be expected, was on a par with a recording of Mr. Waight's final volume in a paper of his (Mr. Waight's) in which the latter gave the tunnel output in terms of pressure per cu. ft. He thought the comparison was about of the same order. In other words, Mr. Waight quoted 35 to 60 mill. for the tunnel. He granted that it was an incorrect way to assess the two things. The heat output of that particular tunnel could be forced up almost indefinitely. They could afford to put a hot plate of 10 lb. on the pressure top and manifold pressure of 35 lb. and force the mixture into the tunnel; and the curious thing to him was it burned it all. Obviously, they were going, at the same time, to assess the actual combustion zone, but it did seem from the convection figure that they could and did get reasonably near to the mouth quite a reasonable degree of combustion. He would admit that the tunnel was impracticable in some operations. He suggested that if the electrical people wanted some component that would improve their induction heating to a considerable degree, they would not falter at installing even a complicated or difficult or expensive burner or component such as the one he had put before them. It all depended, as he had said, on the readiness to make those burners. If they could make them as they could be made by others, no doubt they would get a lot of useful experience.

Mr. Waight had called his attention some months before to another type with a parallel sided tunnel which must of necessity be limited to lower port velocities, and the manifold pressure in the case of that particular parallel sided tunnel was of a much lower order than they could use in their present model. There was no real reason why pre-heat should not be used. All they were doing was to force their gas mixture through the slots and burn it in tapering tunnels. That would be the advantage of it. An induction device could be cheaply made.

Forced Convection

Mr. Waight had mentioned that other people had approached that question of forced convection and that Kilham in his recent paper had given similar calculations on forced convection with a hot sillimanite tube. He thought, as a matter of fact, his calculations were a bit of a departure. He could not remember having seen calculations of convection heat transfer in town gas flames where they actually used a water-cooled tube; yet it was a very simple procedure. The paper had probably over-emphasised the calyx adjustment and, probably with that in mind, it might have been advisable to have incorporated in that paper more particulars of any theoretical air requirement as far as it might be determined and stated within certain limits; and they knew from observations taken on other furnaces that that calyx adjustment did correspond with the theoretical proportions and the total seemed to bear that out. All along, Mr. Waight had said that he (Mr. Smirles) had based those calculated convection figures on an assumed temperature of 1,850°, but they knew that in that flowing unit in that table the flame temperature was falling off. It could only be due to lack of flowing temperature. In other words, those calculated convected heats were really high and only by flame temperature measurement could they find that instead of 385 being their convected heat, it would be something very much lower, say, 285; and the heat transfer to the tube would be 360, so their heat transfer calculated should be 360, and they would not have any latent heat because the tunnel was cool and the gases would be cool. Whether it was within the scope of their researches or not, he did not know. It was really a job for a research team or something of that kind who could devote quite a lot of time in setting up a calibrating device and giving determinations rather than, as they had to do, improvise and take rather shorter cuts on some of those jobs. But, apart from that, they did get results with a definite fall in flame temperature which it was rather reasonable to think did show the trend of heat developments.

In regard to turbulence he had set it at about 2,000. It increased at 3,000 then if they did not correct the combustion

temperature they got a great falling off in flame turbulence. In other words, as they stepped up their mixture, they were increasing their speed and dropped the flame temperature roughly to correspond; and it kept about level. As to mechanical energy, Mr. Waight had quite a different way of attacking those jobs. He (Mr. Waight) had already outlined the mathematical assumptions and mathematical approach to that. But was it not so much more satisfactory to make the proof of it? That was what he really was out for in doing a complete set of tests on the venturi which followed and confirmed Mr. Waight's figures. It was a matter of different approaches to essentially the same problem. The conversion figure of 42% could be improved. In fact, he thought in that rather long burner the conversion was only 50%, and they had not reached optimum. It was a matter entirely of expansion point in the manifold at the back of the slots. If they could afford to make their manifold to reduce their expansion to a minimum (it meant a special design on the back cover of the refractories, perhaps), they could, no doubt, improve the performance a lot; but so far they could employ usefully all the pressure they generated. The time might come when they would want to get a little extra pressure in the manifold.

Mr. **W. Coull** (Birmingham) had had the good fortune to witness much of the work done by Mr. Smirles leading to the paper. The use of the calyx phenomena in experimental work of that nature was introduced by Mr. Smirles before it was generally recognised that that means of accurate assessment were possible. Without any doubt, the information acquired would have been nearly impossible of attainment in the time available, by recognised methods. The silicon ester seemed to produce a very good refractory for that type of work, but it required care in preparation. The accurate measuring of quantities was essential and, coupled with other factors, he could not see that method applied where bricklayers were concerned. The silicon ester itself was rather costly; waste, therefore, must be kept at a minimum.

Although it must be a function of demand, the use of prefabricated refractory units in lengths of, say, 2, 3, 6, and 12 in. would reduce the time taken to make the burner, possibly the cost, and would definitely simplify replacement. If the moulding could not be handled by a manufacturer, he could not see why a plastic core, incorporating the tunnel and grid, could not be used. That core could also be made in unit lengths. As it was at present, it was rather a long and tedious job to make those cores by hand.

The author had mentioned the use of stiff cardboard to form the slots. The absorption of the spirit in the silicon ester by the cardboard had, he thought, a tendency to cause local weakening of the refractory. The life of the refractory part of the burner would not be long, but surely the elimination of more costly methods using contact heating would make that burner interesting, especially if a more easily replaceable refractory unit was available.

Mr. **Smirles** said Mr. Coull had been very closely associated with him in that work; in fact, his help had been most valuable. On the question of the silicon ester, it was a difficult job for a large gas undertaking to know what kind of labour they should put on. There was no reason why people who specialised in that silicon ester moulding should not be called in to make standard units of it. He had no doubt they could do it. In fact, replacements of a certain type could be easily effected. They had tried mixtures other than silicon ester and found these gave very nice mouldings in refractory material. The formation of a plastic core was quite possible, of course.

Mr. **F. Brinsley** (Radiation, Ltd.) said in the paper, on the total air requirement of the burner, the T.A.R. burner had been connected with his name; and he wanted to emphasise that the observations on that burner were the result of team work in their research laboratories. It was first observed in 1938 by one of his colleagues, and they had gradually developed it since then. They had seen a beautiful violet film which they called 'calyx' because of its similarity in shade to the calyx of a flower, and the colour of which might have given the impression that it was due to sulphur; and, in fact, the spectrum of that calyx proved that it was due to sulphur. It was obviously acknowledged that the total air requirement of town gas was of great importance in certain operations. Indeed, the vital importance in certain of the existing methods of determining the total air requirement of the gas were laborious and gave the result some time after the gas of which the sample was representative was used. The great advantage of the T.A.R. burner was that it gave an instantaneous record of the total air requirement of the gas at the moment of use. In certain industrial operations this was, obviously, of very great moment.

Mr. **G. W. F. Cockayne** (Rugby), proposing a vote of thanks to Mr. Smirles, said the fact that it seemed to be a Birmingham paper, coupled with a Birmingham discussion, indicated the strength on the industrial side concentrated in Birmingham. The West Midlands Gas Board were fortunate in having a team of such a high standard to take care of the industrial side. He was very sorry that the new set-up on the industrial side more or less precluded in individual undertakings of the board the direct contacts which they used to have and which, from their point of view, were most admirable. He could only hope that the facilities they had in the past would be continued. He urged the Divisional Industrial Engineers not to tackle problems they could not tackle in a first-class manner, but to bring in the Birmingham staff when necessary to give them the benefit of their expert knowledge and long experience. He suggested, also, to the 'higher ups' in the West Midlands Gas Board that, after provision had been made for training certain other classes in the service, there was nothing more vital than a training course in that area for industrial gas representatives.

Mr. **S. C. Crathorn** (Birmingham) seconded the vote, which was acknowledged by the author.

HANDLING OF MATERIALS

The first of a series of one-day conferences arranged by the Institution of Production Engineers to be held in various centres was held at Bristol on May 13 when about 250 members from many different parts of the country attended. The conference opened with a speech of welcome by Mr. R. S. Brown, President of the Western Section of the Institution. The general introduction was given by Mr. W. C. Puckey, Vice-Chairman of the National Council, who stressed the importance of the subject and said that more consideration should be given to movement of products *from* the works and also to movement of paper work, &c.

W. J. Dimmock (Hoover, Ltd.) and J. R. Sharp (Lansing Bagnall & Co., Ltd.) presented a brief summary of the report of the Productivity Team's findings on their recent visit to America and said that publication of the report had been arranged to coincide with the opening of the Mechanical Handling Exhibition. An important conclusion by the team was that, in general, all the materials handling equipment available in the United States was also available in this country, but in the United States materials handling was given much greater prominence than it was here.

Papers presented at the conference were:—'Methods, Study, Motion and Time Study,' by C. Cooper; 'Bulk Handling,' by R. S. Thorpe (Strachan & Henshaw, Ltd.); 'General Materials Handling,' by H. P. Mott (Vauxhall Motors, Ltd.); 'Fork Trucks and Unit Loads,' by Col. R. T. Hartmann (I.T.D., Ltd.). Also shown was the sound film 'Prelude to Power,' by courtesy of British Ropeway Engineering Company, Ltd.

The President thanked all who had contributed to the organisation of the conference, in particular mentioning Mr. A. Eustace, the Hon. Secretary of the Western Section.

THE GENERAL ASPECT

In the current *Journal* of the Engineers' Guild Mr. K. H. Black, member of Council of the New Zealand Institution said: 'Let us get rid of the notion that we are different from other people, that only engineers have horse-sense and only engineers are worth talking to. We are at least 90% like everybody else, and engineering makes us not more than 10% different. And, so far as we are different, we look just as daft to others as they do to us. Let us get rid, too, of the notion that engineering is so absorbing that we can't find time for other things. I see not the slightest reason to believe that engineering is more absorbing for the engineer than are law, medicine, surgery, architecture, finance, art, or scholarship for their practitioners. . . . The engineer himself should develop and exercise all his faculties, and not merely those that make him an engineer.'

CARBONISING IN CONTINUOUS VERTICAL RETORTS*

By J. M. BROWN, B.Sc., Assoc.M.Inst.Gas E.

Engineer, Saltley Gasworks, Birmingham. Recently Works Manager, Athol Street Works, Liverpool Gas Undertaking

DURING the winter of 1946-47 the shortage of coal compelled the gas industry to use large quantities of imported gas oil, either by abnormal carburetting of water gas or by gasification of oil in horizontal or vertical retorts. By such means essential gas supplies were maintained. Now coal supplies are generally better—though the quality leaves much to be desired—and the use of imported gas oil is discouraged. We must rely on our own coal resources for the supply of gaseous hydrocarbons.

The long term policy calls for more carbonising plant with no doubt its economic and strategic proportions of blue or carburetted water gas plant. Carbonising plant is expensive. A continuous vertical retort installation producing 1 mill. cu. ft. of 450 C.V. gas—*i.e.* 4,500 therms per day—would cost about £100,000. Its construction would require at least 500 tons of steel and cast iron and 1,200 tons of refractory bricks and cement and the plan would not be available for 3 to 4 years. In these circumstances every effort should be made to increase the gas-making potential of existing plant, always provided that the highest possible standards of economic and thermal efficiency are maintained.

This paper details the experience obtained over the past few years in attempts to increase the gas-making potential of a typical continuous vertical retort installation. The gas made was delivered—with or without benzole extraction—on to the town. No C.W.G. plant was available at the works considered.

It should be emphasised that the conclusions reached apply to an undertaking carbonising mainly Lancashire and Yorkshire coals and supplying gas of 450 B.Th.U. per cu. ft. On the plant reviewed it is shown that it is possible to increase the gas-making potential by at least 15%, representing 1 mill. cu. ft. or 4,500 therms per day. The capital expenditure involved did not exceed £2,000.

The dilution of horizontal retort gas by water gas or producer gas has been practised for many years, but until recently these externally generated diluents have not been used in conjunction with continuous vertical retort gas. It has been assumed that any dilution can be economically achieved by steaming within the vertical retort itself and that a gas of given calorific value and composition can be produced with unfailing regularity. The former assumption is questioned, while the claim that steady calorific value and composition is produced may be true, if only one type of coal is carbonised. It is certainly not true when the types of coal carbonised are decided by the coal suppliers.

To expect reasonably constant calorific value of gas from a continuous vertical retort when carbonising some 20 or 30 different types of coal—each type itself varying in ash and moisture—is to set a very difficult task. Attempts to level out variations in calorific value by throughput and/or steam variations, necessitating setting damper alterations, initiate a vicious circle. It is suggested that to achieve the best technical and economic efficiency in a continuous vertical retort installation supplying gas direct to the consumer, the plant should be operated as follows:—

1. Maintain coal throughput per retort at a maximum consistent with reasonably low volatile therms in the coke.
2. Reduce steam admitted to the retort to a minimum sufficient to utilise the sensible heat in the coke for the water gas reaction and to maintain bottom castings cool.
3. When maximum coal throughput and minimum steam admission have been reached, maintain these conditions as closely as possible: throughput will vary with type of coal carbonised and calorific value of gas ex retort house will fluctuate.
4. Control calorific value of gas at inlet holder by admission of externally generated blue water gas or producer gas to the coal gas stream.

The term 'potential daily output (60 retorts)' is used frequently in this paper. It is calculated by multiplying the volumetric and/or thermal output per retort per day by 60. This figure eliminates the effect of varying percentage of retorts off for scurfing or down for repairs. It is used simply for convenience of comparison of output.

Section I

Technical Results— 1939-1947

The carbonising plant at the Athol Street works of the Liverpool gas undertaking consists of two benches of W.D. upwardly heated continuous vertical retorts. Each bench consists of 30 retorts of 62 in. major axis. No. 1 bench is heated by an independent battery of four step-grate producers, while No. 2 bench is heated by five such producers. The additional producer on No. 2 bench was installed to permit the use of breeze as part fuel.

The retorts were completely rebuilt in 1937 and 1938, and the guaranteed outputs after that rebuild were:—

Table A.

C.V. of gas; B.Th.U./cu. ft.	500
Cu. ft. of gas per ton	15,600
Therms per ton	78·0
Thro'put coal/retort/day. Tons	6·9
Therms/retort/day	538·2
Therms/10 in. major axis/day	86·8
Cu. ft. gas/retort/day	107,640
Potential daily output (60 retorts)	
Cu. ft. $\times 10^6$	6·458
Therms	32,292

These results were guaranteed when using Yorkshire nuts containing 8% inerts and 34% volatile matter.

Thermal yields per ton were achieved in normal working, but therms per retort per day were consistently below the guaranteed figures.

The results for the years 1939 and 1940 were:—

Table B.

	1939	1940	*Average*
C.V. of gas B.Th.U./cu. ft.	497	498	498
C. ft. gas/ton	15,980	15,900	15,940
Therms/ton	79·35	79·13	79·24
Thro'put coal/ret/day Tons	6.50	6·30	6·40
Therms/retort/day	516	498	507
Therms/10 in. major axis/day	83·2	80·3	81·8
Cu. ft. gas/retort/day	104,000	100,000	102,000
Potential daily output (60 retorts)			
Cu. ft. $\times 10^6$	6·240	6·000	6·120
Therms	30,960	29,880	30,420

On July 1, 1941, the undertaking's declared calorific value was reduced from 475 to 450 B.Th.U. cu. ft. Throughput of coal was decreased, steam to retorts increased, and the number of discharges of coke reduced from five to four per shift. The aim was to produce a gas ex retort house with a C.V. of 465-470 B.Th.U. cu. ft. and reduce this to 450 by benzole washing.

The results for the years 1941 to 1947 are given in Table 'C'.

TABLE C. RESULTS FOR YEARS 1941 to 1947.

	Jan-June	July-Dec.						Average
	1941	1941	1942	1943	1944	1945	1946	1947	1942-1947
C.V. of gas	495	468	469	467	469	467	466	465	468
Cu. ft. gas/ton	15,800	18,200	17,900	17,800	17,200	17,100	16,800	16,900	17,300
Therms/ton	78·29	85·22	84·06	83·25	80·47	79·92	78·41	78·50	80·66
Thro'put/retort/day ...	6·37	5·65	5·38	5·44	6·14	5·90	5·87	5·98	5·79
Therms/retort/day ...	498	481	452	453	494	471	460	470	467
Therms/10 in. major axis/day	80·3	77·6	72·9	73·1	79·7	76·0	74·2	75·8	75·3
Cu. ft./gas/retort/day × 10^3	101	103	96·5	97·0	105	101	98·5	101	99·8
Potential daily output (60 retorts)									
Cu. ft. × 10^6	6·06	6·18	5·79	5·82	6·30	6·06	5·91	6·06	5·99
Therms	29,880	28,860	27,120	27,180	29,640	28,260	27,600	28,200	28,020

The gas manufactured at the Athol Street works is delivered direct to the district. It is necessary to attempt to control calorific value at inlet holder within close limits, as the holder capacity is very limited. Throughout the period considered in this section calorific value control was attempted by alterations in coal throughput and steam admission to retorts, benzole recovery being compulsory during most of the period. The plant was required to carbonise as many as 20 different types and sizes of coal per day, and no alternative method of control was possible. The alteration in coal throughput and steam admission generally produced the required average calorific value for the day, but hourly fluctuations of calorific value were excessive. For instance, it was not uncommon for the calorific value at inlet holder to vary from a minimum of 430 to a maximum of 460 B.Th.U./cu. ft., in any 24 hour period. This occurred in spite of several alterations in coal throughput and steam admission.

The practice of frequently altering coal throughput and steam pressure has the following serious disadvantages:—

1. The heat requirements of the plant fluctuate rapidly.
2. Damper alterations are numerous, and fail to compensate for the fluctuating heat demands.
3. Steam demands on the waste heat or works boilers are very variable, resulting in fluctuating main steam pressure and erratic rate of steam release.
4. The overall life of a retort setting is decreased when it is subject to fluctuating temperatures.

Section II

In the Autumn of 1947 it was suggested that the method of varying throughput of coal and rate of steam admission to control calorific value was limiting the thermal output of the plant. It was decided to stabilise retort conditions and make extractor drive and steam alterations only once per week. The aim was to increase the thermal output per retort per day by increasing the ratio of coal gas to water gas made within the retorts. Reductions in extractor gaps in steps of $\frac{1}{4}$ in. and in steam pressure in steps of 2-lb. sq. in. were made at the end of each week over a period of five weeks. These comparatively slight increases in coal throughput and decreases in steam pressure were chosen to minimise setting damper alterations and avoid excessive combustion chamber temperature changes.

The results of these experiments are shown in Table D.

Table D

W/E 1947	Nov. 9	Nov. 16	Nov. 23	Nov. 30	Dec. 7
Thro'put/ret/day tons	6·17	6·28	6·23	6·33	6·29
Steam pressure to retorts lb./sq. in.	16	14	12	11	13
Steam % coal carb.	22·1	20·5	19·3	18·4	19·8
C.V. gas ex retort hse.	460	459	463	467	468
Therms/ton	79·25	79·62	82·02	79·46	81·72
Therms/retort/day	489	500	511	503	514
Therms/10 in. major axis/day ...	78·9	80·6	82·4	81·1	82·9
Cu. ft./ret/day × 10^3	106·2	108·9	110·3	107·8	110·0
Potential daily output (60 retorts)					
Cu. ft. × 10^6	6·372	6·534	6·618	6·468	6·600
Therms	29·340	30,000	30,660	30,180	30,840

These results were the highest obtained from the plant since the undertaking's declared C.V. was reduced to 450 B.Th.U./cu. ft. in 1941, representing an increased potential of 0·5 mill. cu. ft., and 2,000 therms per day over the 1945, 1946, and 1947 results.

With the increase in coal throughput a periodic swing in calorific value at inlet holder became apparent.

This swing in C.V. was due to the low capacity of the coke boxes, the number of coke discharges per shift still remaining at four.

These variations of C.V. were levelled out to some extent in the holders, and the stabilised method of working was considered an improvement in spite of this periodicity of the calorific value of the gas. No attempt was made to correct the periodic swing of calorific value, but as the centre line of this swing moved either left or right of the declared value, the benzole plant by-pass was opened or closed. This procedure was not entirely satisfactory, and often failed to return the calorific value to 450 B.Th.U./cu. ft.

At this stage these experiments were interrupted, as No. 2 bench was put to work after resetting. After the bench settled down, the demand on the undertaking's carburetted water gas plants, and the urgency to save gas oil, led to the decision to proceed with external dilution of the vertical retort house gas with producer gas, as described in Section III.

This section would not be complete without reference to the steps taken to maintain operating conditions constant, eliminating all variables except the type of coal carbonised.

To experienced carbonisers the following points will be well known but they are important enough to justify repetition:—

1. The extractors were normally driven by electric motor and considerable variations in speed were common due to load shedding. The standby steam engines were overhauled and gave much more uniform speeds. The engine speeds were checked frequently during each shift.
2. Extractor reciprocating bar strokes were integrated on the usual counter and recorded several times a shift. A recorder-integrator would be of great value to check the operation of the reciprocating bars.
3. Extractor gaps were checked every shift. Measurement of the gap by a steel rule is uncertain. A wooden gauge cut to fit the standard gap was used.
4. Water and steam orifices were cleared weekly with standard reamers. To some operators this may seem an unnecessary task but the number of orifices found partially blocked was surprising. Interruption or restriction of the normal flow of steam or water into a continuous vertical retort will cause combustion chamber temperatures to rocket.
5. Rodding of retorts was carried out strictly to time-table with special attention to this point at change shift times. Even when coal travel was apparently easy the rodding of every hole was carried out.
6. Retort offtakes were cleaned out every shift.
7. The discharge of coke boxes at regular intervals and over a specified time is as important as regular rodding. Coke discharger men tend to lengthen the penultimate draw of the shift so that the last draw will be as short as possible. These points were carefully checked and considerable improvement achieved but we were never satisfied that perfect regularity in this operation was attained.
8. The various types of coal elevated to the retort house were distributed as evenly as possible over the whole length of the bunkers.

In short no factor in the operation of a continuous vertical retort was considered trivial and unimportant. Considerable importance was attached to explaining to the men on the plant the reasons for all the alterations made and instructions given. The time taken on these explanations was considered well spent.

Section III

External Admission of Producer Gas

Prior to the investigation outlined in Section II, it had been decided to install washing and cooling plant, in order to admit producer gas into the coal gas stream from the spare stepgrate producer on No. 2 bench. We should have preferred to use blue water gas externally generated for this purpose but no water gas plant was available at this works and the site was too congested to enable such a plant to be installed. It was calculated that when making a gas ex retort house of 485 B.Th.U./cu. ft. and diluting with producer gas the plant potential would be:—

Table E.

	With Benzole recovery	*Without Benzole recovery*
Coal gas per day		
(60 retorts) cu. ft. $\times 10^6$ at outlet benzole plant	6·40	6·42
C.V. outlet benzole plant	475	485
Possible producer gas admission at 120 C.V. cu. ft. $\times 10^6$	0·48	0·68
C.V. final gas. B.Th.U./cu. ft.	450	450
Total daily potential cu. ft. $\times 10^6$	6·88	7·10
Therms	30·960	31·950

It is well known that a given producer has an optimum gasification rate above or below which the efficiency of the producer and the quality of the gas produced is impaired. It was envisaged that the step-grate producer used in these experiments would be operating inefficiently and making a poor quality gas if the demand on it was of the order of 0·5 mill. cu. ft. per day. The conditions without benzole recovery would give a higher quality producer gas and a much greater plant potential, but it was calculated that optimum conditions in the producer would be obtained if the demand on it was of the order of 0·8 mill. cu. ft. per day. This demand on the producer would necessitate making a gas ex retort house of 490 B.Th.U./cu. ft. upwards, and not extracting benzole.

With this object in mind, extractor gaps in the retorts were progressively reduced. It became increasingly apparent at this stage that the coke boxes were controlling throughput. Further reductions in extractor gaps had no effect on coal throughput per retort per day, and the swing of the calorific value at inlet holder increased in amplitude.

In spite of this limitation set by the capacity of the coke boxes, throughput of coal per retort per day increased from 6·3 tons to 6·5 tons, and the thermal output up to 520 therms per retort per day. The calorific value of gas at inlet benzole plant increased to 475 B.Th.U./cu. ft. and since the benzole plant is limited in capacity the calorific value of the gas at inlet holder increased to 460 B.Th.U./cu. ft.

At the beginning of February, 1948, admission of producer gas to the coal gas stream was commenced. The benzole plant was shut down when the diluent producer gas was admitted. The first three weeks' results under these conditions are given in Table F.

These actual results confirmed the calculations of daily potential output when making a gas of 475 C.V. at outlet benzole plant.

The quality of the producer gas was very erratic during this stage. An average daily admission of this diluent of about 0·4 mill. covered a range of 0·3 to 0·6 mill. cu. ft. As the demand on the producer was reduced its calorific value fell rapidly—*i.e.*, from 115 to 90 B.Th.U./cu. ft. This fall in calorific value necessitated a further reduction in the volume admitted, thereby initiating a vicious circle.

It has been noted earlier in this paper that a retort house gas with a calorific value of 490 B.Th.U./cu. ft. upwards would necessitate the admission of 0·8 mill. cu. ft. of producer gas

Table F.

Week ending	15.2.48	22.2.48	29.2.48
Thro'put/ret/day. Tons	6·59	6·50	6·55
C.V. gas ex retort house	474	470	474
Therms/ton	79·03	79·50	77·41
Therms/retort/day	521	517	507
Therms/10 in. major axis/day	84·0	83·4	81·8
% retorts scurfing	6·4	6·4	7·0
Coal Gas Output (actual) per day			
Cu. ft. $\times 10^6$	6·157	6·172	5·973
Therms	29,204	29,005	28,289
Producer Gas added (actual) per day			
Cu. ft. $\times 10^6$	0·495	0·433	0·423
Therms	445	519	489
C.V. B.Th.U./cu. ft.	90	120	115
Total Gas per Day			
Cu. ft. $\times 10^6$	6·652	6·605	6·396
Therms	29,649	29,524	28,778
C.V. B.Th.U./cu. ft.	445·7	447·0	449·9
Therms/ton	80·24	80·93	78·76
Plant potential/Day (60 retorts)			
Coal gas cu. ft. $\times 10^6$	6·586	6·600	6·428
Producer gas ,,	0·439	0·400	0·460
Total gas ,,	7·025	7·000	6·888
Total therms at 450 C.V.	31,600	31,500	31,000

per day to give an inlet holder gas—without benzole extraction—of 450 B.Th.U./cu. ft. To achieve this it was necessary to increase the number of coke discharges from four to five per shift. The co-operation of the shiftmen doing this work was sought and won, and with some minor alterations in cleaning duties the extra coke discharge per shift commenced on March 1, 1948.

Coal throughput increased immediately to approximately 7·4 tons per retort per day; the calorific value of the gas ex retort house increased to 490-500 B.Th.U./cu. ft., and the demand on the diluent producer was increased to more than 800,000 cu. ft. per day.

The results for the three weeks following the increased number of coke discharges per shift are shown in Table G.

Table G.

Week ending	7.3.48	14.3.48	21.3.48
Thro'put/ret/day tons	7·09	7·54	7·35
C.V. gas ex Retort House	490	503	503
Therms/ton	75·06	73·38	75·37
Therms/retort/day	532	554	554
% Retorts scurfing	6·6	7·1	5·9
Coal Gas Output (actual) per day			
Cu. ft. $\times 10^6$	6·084	6·093	6·214
Therms	29,821	30,667	31,278
Producer gas added/day (actual)			
Cu. ft. $\times 10^6$	0·729	0·999	1·027
Therms	874	1,199	1,233
C.V.	120	120	120
Total Gas per day (actual)			
Cu. ft. $\times 10^6$	6·813	7·092	7·241
Therms	30,695	31,866	32,511
C.V.	450·5	449·0	449·0
Therms/ton	77·26	76·22	78·34
Potential Daily Output (60 retorts)			
Coal gas cu. ft. $\times 10^6$	6·514	6·600	6·600
Producer gas	0·790	1·060	1·060
Total gas	7·304	7·660	7·660
Total therms at 450 C.V.	32·870	34·470	34·470

Section IV

Three complete full-scale tests have been made to compare the technical results obtained when making a gas ex retort house of 465 B.Th.U./cu. ft. and extracting benzole with those obtained when making gas of 500 B.Th.U./cu. ft. with no benzole recovery, and admitting producer gas externally generated.

During the July, 1947 test (Test I) only No. 1 bench was gas-making. This test was carried out with all retorts working—*i.e.* no scurfing. In the March, 1948, test (Test 2) 6·2% of the retorts were off for scurfing.

The fuel consumption of the settings is therefore not comparable. It is calculated that if all the retorts had been working in Test 2, the fuel consumption in the setting producers would have been approximately 0·340 therm per therm of coal gas.

In Test 3 no retorts were off for scurfing and the volume of producer gas admitted to the coal stream was beyond the capacity of the Electroflo orifice meter. No separate coal gas and producer gas outputs were determined in this test.

In contrasting the results of Test 2 with those of Test 1, the following points are of interest:—

1. The combustion chamber temperatures were of the same order.
2. The throughput of coal per retort per day was 18·8% greater.
3. The steam admitted to the retorts was decreased from 21·1% to 16·2% of the coal carbonised—*i.e.* by 23%.
4. The yield of coal gas per ton of coal carbonised was 6·3% less; the combined thermal yield of coal gas and producer gas per ton of coal carbonised was 2·8% less.
5. The thermal output per retort per day was increased by 11·4%.
6. The total daily potential of the works was increased by 19%.
7. The dry coke available for sale from the works was increased by 33%.

	Test 1.	*Test* 2.	*Test* 3.
Date of test	July, 1947	March, 1948	Nov., 1949
Period of test	7 days	7 days	4 days
Beds at work	5	10	10
Retort days	210	394	240
Producers at work heating settings	4	8	8
Producers making diluent gas	Nil	1	1
Augmentation at inlet W.H.B's.	Nil	Nil	
Combustion chamber temperature °C.			
Bottoms; Average	1,360	1,360	1,375
Maximum	1,420	1,460	1,450
Minimum	1,190	1,240	1,180
Tops: Average	1,060	1,050	1,035
Maximum	1,140	1,120	1,180
Minimum	940	940	910
Steam to retorts % coal carbonised	21·1	16·2	15·6
Coal carbonised: Wet: Tons	1,314·6	2,932·1	1,787·3
Thro'put/ret/day ... Tons	6·26	7·44	7·45
Type of coal %			
Lancs.	51·8	36·0	16·0
Yorks	Nil	51·0	78·0
Derby	Nil	Nil	Nil
Mixed Stock	48·2	13·0	6·0
Analysis of coal H_2O%	6·4	5·7	6·2
Ash	5·7	6·4	5·2
V.M.	34·3	33·9	32·6
F.C.	53·6	54·0	56·0
Sw. No.	4½	4½	6½

Gaseous and Thermal Outputs	*Test* 1.	*Test* 2.	*Test* 3.
Coal Gas. Cu. ft. 60° F. & 30 in. Satd.	22,797,000	44,612,000	—
C.V. B.Th.U./cu. ft.	461	493	—
Therms	105,203	219,842	—
Therms/ton coal	80.03	74·98	—
Therms/retort/day	501	558	—
Cu. ft./retort/day	108,600	113,200	—
Producer Gas. 60° F. & 30 in. Satd, Cu.ft.	Nil	6,089,000	—
C.V. B.Th.U./Cu.ft.	—	134	—
Therms	Nil	8,159	—
Therms/ton coal	Nil	2.78	—
Therms/ton coke	Nil	228·2	—
Total Gas. Cu. ft. 60° F. & 30 in. Satd.	22,797,000	50,701,000	29,345,000
C.V. B.Th.U./cu. ft.	461	450	453
Therms	105,203	228,001	132,818
Therms/ton coal	80·03	77·76	74·31
Benzole Extracted: Gals.	2.321	Nil	Nil
Gal./ton	1·77	Nil	Nil
Volume gas at inlet holder cu. ft.	22,704,000	50,701,000	29,345,000
Therms gas at inlet holder	101,954	228,001	132,818
Total Daily Potential Output (60 *retorts*)			
Inlet Benzole Plant.			
Coal gas: cu. ft. × 10^6	6·516	6·792	—
Therms	30,060	33,480	—
Prod: gas cu. ft. × 10^6	Nil	0·927	—
Therms	Nil	1,242	—
Total gas. cu. ft. × 10^6	6·516	7·719	7·336
Therms	30,060	34,722	33,205
Inlet Holder.			
Total gas. cu. ft. × 10^6	6·487	7·719	7·336
Therms	29,130	34,722	33,205

Coke Made and Used	*Test* 1.	*Test* 2.	*Test* 3
Total made; dry: cwt/ton coal	11·33	12·52	12·45
% ash in dry coke	10·7	10·8	11·4
C.V. of dry coke B.Th.U./lb.	12,680	12,590	12,480
Used in setting producers.			
dry; cwt/ton coal	1·99	1·87	1·63
dry: % coal carb	9·95	9·35	8·13
Used in diluent producer:	—	0·22	0·27
Available for sale.			
dry; cwt/ton coal	9·34	10·43	10·47
corrected to 8% H_2O cwt/ton coal	10·15	11·34	11·38

Efficiency of Gas Production.			
Coal Gas only.			
Therms in dry coke to producers	38,000	79,360	—
Therms in coal gas made	105,203	219,842	—
Producer fuel therms per therm of coal gas	0·361	0·361	—
Efficiency of gas production %	69·4	69·4	—
Diluent Producer Gas only			
Therms in 100 lb. dry coke	—	12·8	—
Therms in producer gas; gross	—	10·7	—
Coal gas efficiency %	—	83·6	—

Thermal Efficiency of Works	*Test* 1.	*Test* 2.	*Test* 3.
(a) Therms in coal	294·0	300	291·4
Therms in gas (incl. benzole)	80·03	77·76	74·3
Therms in coke for sale	132·4	147·1	146·3
*Therms in tar	23·3	19·80	24·7
(b) Total therms	235·73	244·66	245·3
Thermal efficiency $\frac{b}{a} \times 100$ %	80·1	81·6	84·2
Fuel Expenditure Index	19·9	18·4	15·8

[*The yield of tar was not determined over the short period of these tests.

The average yields over a month in July, 1947, and March, 1948, have been taken as 13·0 and 11·0 gal./per ton respectively

The average yield of tar during November, 1947, was 13·7 gal./per ton.]

Comparative Net Prime Costs

	Test 1.	*Test* 2.	*Test* 3.
Therms before washing	105,203	228,001	132,818
Coal carbonised Tons	1314·6	2932·1	1787·3
Coke available for sale (8% moisture) Tons	567·0	1495·0	873·6
Breeze available Tons	100·0	166·0	143·4
Tar available for sale Gal.	17,090	32,253	24,540

PARTICULARS	*Pence per Therm*		
	Test 1.	*Test* 2.	*Test* 3.
Coal used (at 62/10 per ton)	9·42	9·70	10·15
Less Credits:			
Coke avail. for sale (at 50/2 per ton)	3·24	3·95	3·96
Breeze " " " (at 13/6 per ton)	0·15	0·12	0·17
Tar " " " (at 5½d. per gal.)	0·89	0·78	1·02
	4·28	4·85	5·15
Net cost of prime materials	5·14	4·85	5·00
Labour (carbonising)	0·40	0·37	0·36
Labour (coal handling)	0·09	0·10	0·10
Total prime labour	0·49	0·47	0·46
Net prime costs per therm	5·63	5·32	5·46

It will be noted that the thermal efficiency of the works was increased under the conditions of Tests 2 and 3 compared with Test 1. Also the net prime cost per therm of gas was decreased.

The method used to increase the gaseous output has one serious disadvantage—the coke available for sale is increased. This extra coke would be embarrassing and costly in areas where the coke market is depressed and the method would be

inadmissible unless the extra coke made could be absorbed in a blue or carburetted water gas plant.

In Table H the total gaseous potential of the plant and the resultant dry coke yield under the conditions of Tests 1 and 2 are compared with the calculated yields of gas and coke for sale if water gas, blue and carburetted had been available. It will be noted that it would be necessary to produce 4·131 mill. cu. ft. of C.W.G. at a C.V. of 379 B.Th.U./cu. ft. if the surplus coke over the conditions of Test 1 is all to be absorbed.

Table H.

Operating Conditions:—	1. *Test* 1.	2. *Test* 2.	3. *B.W.G. diluent at* 290 *C.V.*	4. *C.W.G. diluent at* 350 *C.V.*	5. *C.W.G. diluent at* 379 *C.V.*
Coal throughput, tons/retort/day	6·26	7·44	7·44	7·44	7·44
Potential coal gas yield (60 retorts) cu.ft. $\times 10^6$	6·516	6·792	6·792	6·792	6·792
C.V. coal gas	461	493	493	493	493
Diluent admitted cu.ft $\times 10^6$ ...	—	0·927	1·825	2·920	4·131
C.V. of diluent	—	134	290	350	379
Dry coke consumption of diluent: Tons	—	4·9	29·3	44·3	62·7
Total dry coke for sale per day: Tons	175·0	232·8	208·4	193·4	175·0
Surplus dry coke per day over Test 1: Tons	—	57·8	33·4	18·4	*Nil*

The life of a retort setting is not a question of 'days carbonising' but what quantity of coal it can carbonise efficiently before a rebuild is necessary. This life can be assessed as tons of coal carbonised per 10 in. retort major axis and an accepted figure on this basis is 2,500 tons during the retort's overall life—*i.e.* from rebuild to rebuild of the retort monolith—during such a life two retort face repairs are usually required.

Our experience on the plant considered when working nominal throughputs and under the conditions enumerated in Section I was that the retort life did not exceed 2,500 tons per 10 in. major axis. It is only fair to state that the plant was subject to interruptions due to air raids and that generally the labour force on the plant was unsatisfactory during this period.

Throughout the period covered by the experiments on increased throughput of coal per retort the works was operated on base load conditions. A base load works is here defined as one in which the plant is maintained at full output the whole year round for a period of years. Week-end, holiday, and peak-load variations are not allowed to interfere with the operation of such a works.

On existing evidence we expect to carbonise 1,600 tons of coal per 10 in. retort major axis before the first retort face repair is required and if the operating conditions are maintained an overall life of 3,000 tons per 10 in. retort major axis is anticipated. Assuming a monolith rebuild is then necessary an increased life of 20% will be achieved and the cost of a retort face repair saved.

It is not possible to say whether the excellent condition of the retorts is due primarily to base load working or to steady operating with high throughput and minimum steaming. It is believed that both factors contribute to an extension of retort life.

MODERN STEAM-RAISING PLANT*

By J. T. LEWIS

Newcastle Division, Northern Gas Board.

UNTIL last year the steam required at Redheugh gasworks was raised by 11 Lancashire boilers plus a waste heat boiler. Now the demand is met by two water tube boilers and the waste heat boiler. These water tube boilers are the Clarke Chapman tri-drum boiler, and each boiler is designed to burn coke breeze and produce 30,000 lb. steam per hour, with an overload up to 35,000 lb. if necessary. They have been tested at 350 lb. sq. in., and at the moment the working pressure is 100 lb. sq. in., though this can be raised to 175 lb. if desired.

The layout of each boiler consists of:—

(*a*) Three drums—two steam and one water drum—connected by 432 generating and 60 circulating tubes, each of 3¼ in. diameter, plus 34-1¾in. tubes for superheating.

(*b*) Fuel hopper with a capacity of 60 tons. The hopper is fed automatically by an electric winch working in conjunction with a shuttle belt conveyor.

(*c*) Grate fitted by International Combustion Co., Ltd. It is a travelling grate electrically driven from the front driving sprockets. The fuel is fed from the hopper through the shutters (which control the fire thickness) on to the grate, giving a combustion area of 178 sq. ft.

(*d*) Howden Ljunstrom air heater whereby the hot waste gases leaving the boiler are used to heat up the incoming air required for the forced draught. The heater consists of a revolving grid drum of large surface area which is continually being heated up by the waste gases and cooled as it revolves and comes into contact with the air.

(*e*) Two Davidson fans. The forced draught fan which draws in air from the boiler house and passes it via the air heater to underside of the grate, and the induced draught fan which draws the waste gases away from the boiler to the chimney.

The fuel used is coke breeze and the boiler was designed to burn breeze of a calorific value of 9,400-9,500 B.Th.U./lb.—*i.e.* about 34% incombustible material, ash and moisture. Since the boiler was installed all classes of breeze (coke oven, continuous vertical, and horizontal) have been used with only slight adjustments to the controls. From our experience the calorific value is of less importance than the sizing. With the correct sizing of nothing above ¾ in. and not more than 35% below ¼ in. there is no trouble. If, however, the breeze is too small, there is an excessive loss due to fines and grit being carried away before being burnt and subsequently dropped into the grit chutes at the rear of the boiler. If the breeze is too big the fire moves towards the rear of the boiler, the steam output falls, and a large percentage of unburnt coke passes over into the ash hopper. The speed of the grate and the thickness of the fire can be controlled to a fine limit and on an average a fire thickness of 6 in. and a grate speed set to give the breeze 40-45 minutes on the grate are giving satisfactory results. The clinker and ash are removed by the clinker dam resting on the grate, and dropped into the ash hopper, where they are periodically removed by hand truck and elevated to an overhead storage hopper outside the building.

The forced draught, necessary for the combustion, on leaving the air heater enters below the grate at 300°F. approx. The actual disposition of the air is controlled by five dampers along the length of the grate. For coke breeze the best results are obtained by having the first three dampers closed with only the two rear dampers open, so as to get the breeze almost to ignition temperature before admitting air. The path of the hot gases is baffled as much as possible to ensure maximum recovery of heat and the waste gases finally leave the boiler at 600°F. approx., pass through the air heater which reduces their temperature to 400°F. approx., and then up the chimney via the

*Paper to the Northern Junior Gas Association, April 28, 1950

induced draught fan. These temperatures are about average but they tend to rise as the boiler gets a layer of flue dust over the tubes, &c. Provision is also made for the air and the waste gases to by-pass the air heater if necessary. Carbon dioxide recorders are installed at the boiler outlet and under normal conditions 12% CO_2 is obtained. There are eight soot blowers distributed throughout the boiler from the combustion chamber to the outlet air heater and these are blown once per shift. Should the steam output fall, through the quality or sizing of the breeze, the heating can be augmented by using gas (at a rate of 9,000 cu.ft. per hour) from 12 gas jets fitted to the shutter doors; but these are only used in an emergency.

The raw water supplied to the works has a total hardness of 8°-10° and this water is softened by a Neckar Zeolite softener down to zero hardness. It is then conditioned with caustic soda to give the required alkalinity and sodium sulphate to maintain the sulphate ratio necessary to prevent caustic embrittlement. The feed water is stored in a tank of 8,000 gal. capacity inside the boiler house. It is pumped from this tank through the feed water heater where its temperature is raised from 140°F. to 200°F. at the expense of the waste steam from the pumps and fans. The water enters the boiler through a distributor in the top drum. The level in the boiler is maintained at almost constant level by means of the Copes regulator so that the amount of water entering the boiler depends upon the output of steam. The water level rarely varies by more than 1 in., but in case of emergency the drum is fitted with both high and low water alarms.

The steam leaves the drum and passes through the superheater tubes where it receives about 50°F. superheat making a total steam temperature of 400°F., though the amount of superheat varies with the state of the boiler. The auxiliaries, which include pumps, fans, &c., can be driven by superheated steam from the range or by saturated steam taken off by a separate line from the drum. On an average about 5,000 lb. steam per hour is used on the auxiliaries. The only other loss from the boiler is the continuous blowdown, which can be adjusted to give the required conditions of alkalinity, &c., in the boiler. The blowdown is led away to a deconcentrating tank outside the boiler house, where the flash steam is passed direct into the feed water and the heat in the residue partly recovered by passing it through a coil in the feed tank before going to waste.

The boilers are controlled from an instrument panel on the firing floor and each boiler has its own set of instruments and controls.

One operator can easily control both boilers, and the total manpower is three men per shift.

During the twelve-month period to September, 1949, results were very satisfactory, once the teething troubles were overcome. On an average each boiler uses about 45-50 tons of breeze per day, produces 7 lb. of steam per lb. of fuel, and gives an efficiency of approximately 70%. The uniform pressure now available to all parts of the works has resulted in increased efficiencies. This is especially noticeable at the C.W.G. plant where previously the output was reduced through lack of pressure, so that in all ways the boilers have justified their installation.

Automatic Control

Since the paper was written, the boilers have been working for over six months on automatic control. The working medium is compressed air at 80 lb./sq. in. through suitable reducing valves to the controls.

The boiler output depends on the demand, and if this demand increases a falling steam pressure would result. It is this falling steam pressure which brings the various controls into operation to maintain a constant pressure.

(*a*) Falling steam pressure operates the steam supply to the F.D. fan and speeds it up. This would tend to increase the differential pressure between the F.D. and I.D. fan (*i.e.*, the combustion chamber conditions) but the furnace draught controller immediately speeds up the I.D. fan to establish equilibrium.

(*b*) The steam and air flow pens on the Bailey meter tend to separate. This difference actuates the rheostat governing the grate speed and the grate is speeded up, thereby increasing the fuel supply so that with the combination of the above changes the outlet steam pressure is kept constant irrespective of the load.

Should the steam demand fall, the procedure is reversed.

INDUSTRIAL DERMATITIS

Dr. C. N. D. Cruickshank, of the Medical Research Council Industrial Medicine Research Unit, Birmingham, stated at the recent Royal Sanitary Institute Congress that industrial dermatitis in the engineering industry accounts for the loss of about 500,000 working hours, or 98,000 man-weeks, per annum, according to studies of time lost by the compensation cases of three large Birmingham factories. The engineering industry contributed more than 40% of industrial dermatitis. Where there was a high labour turnover, the incidence of dermatitis was likely to be high. Dermatitis, in many cases was caused by the worker's failure to understand the nature of the substances he was handling. The number of certified cases involving more than three days loss of work rose from 3,600 in 1939 to more than 10,500 in 1944, though since then there had been a slight drop in numbers.

THE ENGINEER'S RESPONSIBILITY

In an address to the Yorkshire Branch of the Engineers' Guild Mr. Robert Chalmers said that the engineer's first responsibility was to be competent and diligent in his daily work for his employer or his client. It might be said that his responsibility in that work was a responsibility to the employer or client and not to the community; but since engineering was in fact a service to the community it might be said that in their daily work engineers discharged a responsibility to the community. The question was rather whether the engineer had any responsibility to the community beyond doing his job well and faithfully. His job would not be well and faithfully done if it occupied only business hours. He must devote time outside of those hours to keeping abreast of developments by studying the technical Press and other sources of information and by seeing what he could of other engineers' works. He might have to post himself on branches of engineering work not hitherto within his knowledge and experience. His knowledge of engineering could not be too wide or too deep, and engineering was a very big, a very demanding, and a very absorbing pursuit. When they considered that the engineer must also find time for exercise, and that he had family and other private affairs to see to, he might very well ask how anything more could reasonably be asked of him.

And yet, if that was the whole answer, it became fairly obvious that the engineer must be content with a subordinate status in the community. If it took them all their time just to be engineers, while other people could manage, besides doing their daily jobs, to play a wider part in the life of the community, then theirs would be the initiative and the prestige, and they must be content to furnish their advice when it was asked for, to do what they were told, and, for the rest, to find what solace they could in their cloistered specialist studies and their family and private affairs.

If the engineer liked to accept the position, it did not matter, except that there must surely occur to some the disturbing question whether the community, in that case, would be getting all the benefit that it could get from the profession; whether there were not many people every day paying for goods and services which were not value for their money, just because they did not know what they knew and because they were unaware of their own ignorance; whether there were not authorities and administrators taking wrong or imperfect decisions affecting the community.

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